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An ESSAY *to improve the* THEORY *of* DEFECTIVE SIGHT. *By the Rev.* JOHN STACK, *F.T.C.D. and M.R.I.A.*

THE common theory of defective ſight attributes the confuſion in imperfect viſion to the interſection of the rays of each pencil that enters the eye, in points either *before* or *behind* the retina. It ſtates the former of theſe defects as proceeding from too great a convexity of the cornea, or of the chryſtalline humour, or of both; and the latter from the contrary ſtructure of thoſe parts of the eye. Beſide theſe ſcarce any other cauſes are aſſigned, or any farther explanation of the defects given. Read Jan. 5, 1788.

THIS, however, ſeems inadequate to the ſolution of ſeveral phænomena in caſes of defective ſight that frequently occur; ſuch as the following:

1. I HAVE frequently cauſed ſhort-ſighted perſons to place a printed book a little beyond their limits of diſtinct viſion; then

applying

applying a card, with a ſmall hole made in it, to the eye, they read at the above-mentioned diſtance with great eaſe.

2. OBSERVING the effect of this experiment to be more ſtriking than uſual in a perſon the pupil of whoſe eye was very large, I meaſured the diſtances at which he could read when the pupil was dilated, and when it was contracted, and found the former leſs than the latter by about two inches.

N. B. THESE caſes are the more remarkable, as the quantity of light incident from the object on the eye is diminiſhed in each of theſe experiments *, and conſequently the vividneſs of the pictures on the retina; therefore a conſiderable degree of diſtinctneſs muſt have been procured to overbalance the diſadvantage that the loſs of light occaſioned.

3. I HAVE met with caſes, though not frequently, of defective ſighted perſons whoſe ſight was ſuch as to be incapable of being aſſiſted by any double-concave or convex glaſſes. Some of them found viſion a little more diſtinct through a pin-hole *in ſtrong light*, others not.

THESE caſes do not appear at all explicable on the vague theory of defective ſight generally received; and perhaps others of a ſimilar deſcription may occur, or have already occured to more accurate and extenſive enquirers.

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* Hence the reaſon why theſe experiments are attended with more remarkable effects in ſtrong than in weak light.

THAT ſuch phænomena however may reſult from various defects in the ſtructure of the eye, will be evident to any one who conſiders the exact conformation and adjuſtment of its parts neceſſary to produce perfect viſion. Theſe requiſites indeed are ſo many, and of ſo ſubtile a nature, that it ſeems much more ſurprizing that ſo delicate an organ ſhould not be oftener rendered imperfect by accident or natural infirmity, than that ſo many inſtances of defective ſight ſhould be met with.

A DEVIATION from the juſt form or refractive power of any of the different humours might be ſhown (from optical principles) capable of cauſing the phænomena above-mentioned; but as the chryſtalline humour is the principal inſtrument in viſion, it will be ſufficient to point out the effects ariſing from any deficiency in its ſtructure, eſpecially as the number and minuteneſs of the circumſtances neceſſary to its perfection make this humour more liable to incur the defect than either of the others; and as any remedy applicable to the removal of errors hence ariſing will be found equally ſo to that of errors occaſioned by the imperfection of the aqueous or vitreous humours.

THE chryſtalline humour being in the form of a double convex lens, it is evident that when parallel rays are incident on it, thoſe fall more obliquely on its ſurface which are more remote from the vertex or middle point of that ſurface. Now if that humour were of uniform denſity, the refraction of the remote rays would ſo far exceed that of the central ones as to interſect each other nearer to the chryſtalline than the mutual interſection of the more central rays; therefore if one of theſe interſections (or foci) be at the retina, the other muſt be removed from it, and conſequently a confuſion would enſue in the picture on the retina.

It is however well known that nature has uſed an admirable precaution againſt this imperfection, by gradually diminiſhing the denſity (and therefore the refractive power) of the chryſtalline from the centre toward the edges; ſo that the exceſs of refraction ariſing from obliquity of incidence ſhould ſerve as a compenſation for the defect of it, owing to the diminution of denſity, and thus *in perfect viſion* produces this effect, that both the extreme and central rays of the incident pencil ſhould be brought to a common focus exactly on the retina.

Let us now ſuppoſe a chryſtalline humour of ſuch a form as it uſually has in a perfect eye, and at the central parts of a juſt denſity, but whoſe denſity is not ſufficiently diminiſhed in proceeding from the centre to the edges: From what has been juſt obſerved on the caſe of uniform denſity in the chryſtalline, it is plain that the exterior rays of the incident pencil, and thoſe only, will in the preſent caſe ſuffer too great a refraction, and produce confuſion in the picture on the retina; conſequently if theſe be intercepted, and the central rays alone tranſmitted to the eye (as is done in the firſt experiment by the pin-hole) viſion will be diſtinct, and no obſtacle to its perfection will remain but what ariſes from want of ſufficient light. Vid. Fig. I.

Fig. II. Even though the denſity of the chryſtalline were every where too great as well toward the centre as toward the edges, yet

yet as the diffuſion O S, occaſioned by the central rays, is far leſs than T V, that cauſed by the exterior rays, viſion, though not rendered perfectly diſtinct by the excluſion of the exterior rays, will be made more clear than before, unleſs the denſity be very much greater than it ſhould, in which caſe the diffuſion O S might be ſo great as to impede viſion entirely, as well as the diffuſion T V, which is greater than it.

I HAVE here ſuppoſed the rays parallel, for the purpoſe of conſidering the view of remote objects; but the reaſoning will equally apply to rays ſenſibly diverging, and ſo will illuſtrate as well the view of nearer objects.

THESE obſervations, if juſtly founded, might ſerve to ſhew the reaſon of what occurred in the ſecond experiment, where the confuſion of viſion was ſo much diminiſhed by the contraction of the pupil, the *Iris* in ſuch a caſe intercepting thoſe rays which cauſed a confuſion when the pupil was dilated; in the ſame manner as the card in the firſt experiment intercepted the rays that cauſed confuſion to the naked eye.

IT appears to me that the defect of all ſhort-ſighted perſons who are aſſiſted by concave glaſſes is probably of that kind repreſented in Fig. II. becauſe as the refraction of a lens affects any rays that fall on it (except that in its axis) and as the refraction is conſtantly greater the more remote the incident rays are from the axis, ſo where ſuch a glaſs renders viſion diſtinct, errors of refraction muſt have taken place in the eye, previous to the

the application of the glaſs, equal and contrary to thoſe refractions which have removed them.

If the defect were not of this nature, but that all the rays were brought to a focus in the ſame point before the retina, a Fig. III. lens, the refraction of whoſe central parts would bring the rays near the axis to a focus at the retina, will, by the greater refraction of its exterior parts, remove the focus of the more remote rays behind the retina. Or even though all the rays did not meet in a point, yet if their interſections were all very Fig. IV. cloſe to each other, and at a conſiderable diſtance from the retina, the effect of a concave glaſs would be the ſame as before, and while it deſtroyed the diffuſion of the central rays, would leave a diffuſion of the exterior rays remaining, or vice verſa.

On the other hand, if the foci of the extreme and central Fig. V. rays within the eye fall before the retina, and are too diſtant from each other, no double concave of the uſual form (i. e. of equal curvature on each ſide) can deſtroy the error of the one kind of rays, without generating or leaving one of the other kind.

Now, if any glaſs can be contrived in which the quantity of refraction of the central rays can be made the ſame as in a double concave, while that of the exterior rays is diminiſhed, it would ſeem that the former error might be avoided; and on the contrary, that the laſt mentioned error might be compenſated, if the glaſs were ſo contrived as to make the exterior rays ſuffer a greater refraction than they do in the double concave, the refraction of the central rays remaining the ſame as before. And perhaps it will appear that theſe effects may be produced by a concavo-convex glaſs of greater curvature on the concave ſide than on the convex, eſpecially if the thickneſs of ſuch a lens be made greater than uſual ; becauſe the thicker the lens is, the nearer will an exterior ray be brought to the vertex of the ſecond ſurface, and therefore its incidence, and conſequently its refraction by that ſurface, will be the leſs, as in Fig. VI. ; vice verſa in Fig. VII.

We ſee that in the double concave the refraction of an exterior ray, by the firſt ſurface, is greater than that of a central ray, and as its effect is to cauſe a divergence, the refraction of the firſt ſurface will add more to the effect of the ſecond ſurface (which is alſo to cauſe divergence) upon the exterior rays than upon the central.

1. In the ſame manner in the concavo-convex (the rays falling on the convex ſide) the refraction of the exterior rays by the firſt ſurface is greater than that of the central rays; but theſe refractions are decrements of the divergence cauſed by the ſecond ſurface ; therefore the divergence of the exterior rays is more diminiſhed than that of the central rays, and therefore may be made leſs than that of the exterior rays made by a double concave, while the divergence of the central rays cauſed by both is the ſame.

2. Let the rays fall on the concave ſide, Fig. VIII. In this caſe the divergence of the exterior rays by the concave is greater than

that of the central rays; hence the incidence of the exterior rays on the ſecond ſurface may be made leſs than that of the central rays, and therefore the refraction of the former ray into air may be leſs than that of the latter; that is (ſince theſe refractions cauſe a convergence) the divergence of the exterior rays is leſs diminiſhed than that of the central, therefore the exterior rays will for both reaſons diverge more than the central.

THIS, it will be ſaid, is equally effected by a double concave; but if the curvature of the firſt ſurface in the concavo-convex be conſiderable in reſpect of that of the ſecond ſurface, it may be brought to paſs that the incidence of the exterior rays on the ſecond ſurface ſhall be of a different affection from that of the central rays, and therefore that the refraction of the ſecond ſurface may augment the divergence of the former, while it diminiſhes the divergence of the latter, and thus cauſe a greater divergence of the exterior rays than can be effected by the double concave, while the divergence of the central rays cauſed by both is the ſame.

THESE expedients ſeem capable of correcting the unuſual errors of ſhort ſight, that cannot be removed by any double-concave glaſs, if they ſhould be occaſioned by the cauſes that I have ſuppoſed, i. e. by conſiderable errors of ſphericity.

AND it ſeems probable, from what has been ſaid, that ſuch defect is occaſioned by thoſe cauſes, where perſons of the above deſcription are aſſiſted in viſion by looking through a pin-hole, and that they may try the effect of the concavo-convex poſſibly with advantage.

And if any chromatic errors ſhould accompany theſe errors of ſphericity, as probably there would, they will be diminiſhed or removed by the diſperſion that attends the refraction of the glaſs.

But where the application of a pin-hole to the eye does not render viſion more diſtinct, the defect probably does not ariſe from ſuch imperfect ſtructure* of the eye as has been ſuppoſed, but from ſome other cauſe, as turbid humours, calloſity of the retina, or reflexion of the oblique rays from the ſides of the eye, by which the pictures on the back part of the retina would be confuſed.

Dr. Porterfield and others account for the diſtinctneſs afforded to ſhort-ſighted perſons by looking through a pin-hole, by the diminution of the breadth of the pencil incident upon the retina, ſuppoſing ſtill that all the rays *interſect in one point within the eye*; but beſide that the breadth is not ſo much leſſened on that hypotheſis as on the hypotheſis here given, and therefore the phænomenon not ſo adequately accounted for, it alſo ſeems a very extraordinary and improbable ſuppoſition, that while all the numerous parts of ſo delicate an organ as the eye are diſordered or deranged, yet that ſo exact a *harmony in error* ſhould be obſerved among them, as to bring the rays of every different poſition to one common interſection at an improper place.

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* It is poſſible that the ſtructure of the eye might be ſuch as that the foci of the exterior and central rays would fall at different ſides of the retina, which defect would not be eaſily remedied; but even this I conceive might be accompliſhed by combinations of different lenſes, like the compound object-glaſſes of Dolland.